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(54) **THERMALLY TUNED COAXIAL CABLE FOR MICROWAVE ANTENNAS**

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See application file for complete search history.

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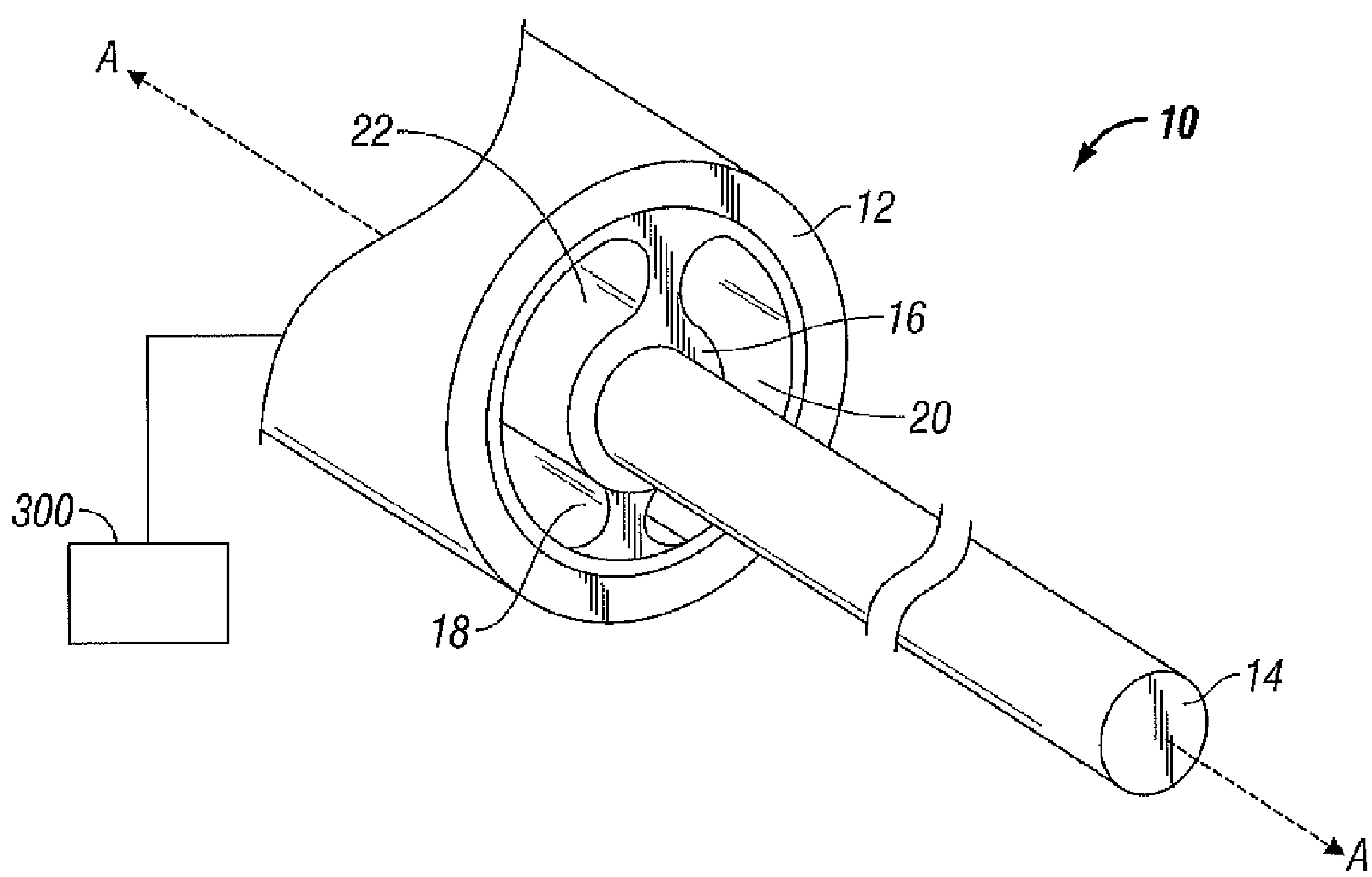
(57) **ABSTRACT**

A coaxial cable, including an outer conductor and an inner conductor adapted to connect to an energy source for treating tissue and first and second dielectric materials disposed between the inner conductor and the outer conductor which position the inner conductor relative to the outer conductor in general concentric relation thereto. The first dielectric material has a first coefficient of thermal expansion and the second dielectric material has a second coefficient of thermal expansion different from the first coefficient of thermal expansion.

20 Claims, 8 Drawing Sheets



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European Search Report EP 98958575.7 dated Oct. 29, 2002.
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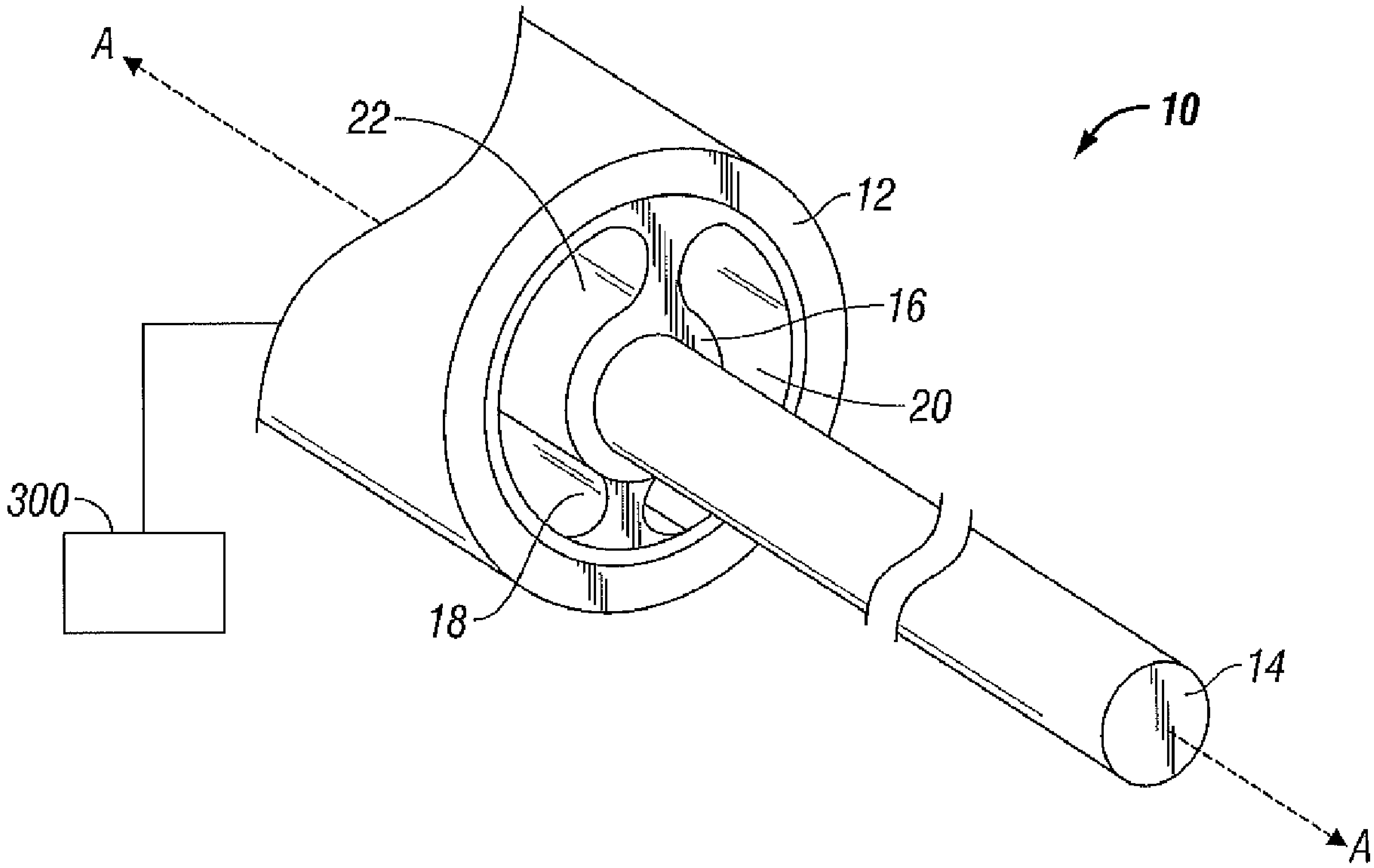

FIG. 1A

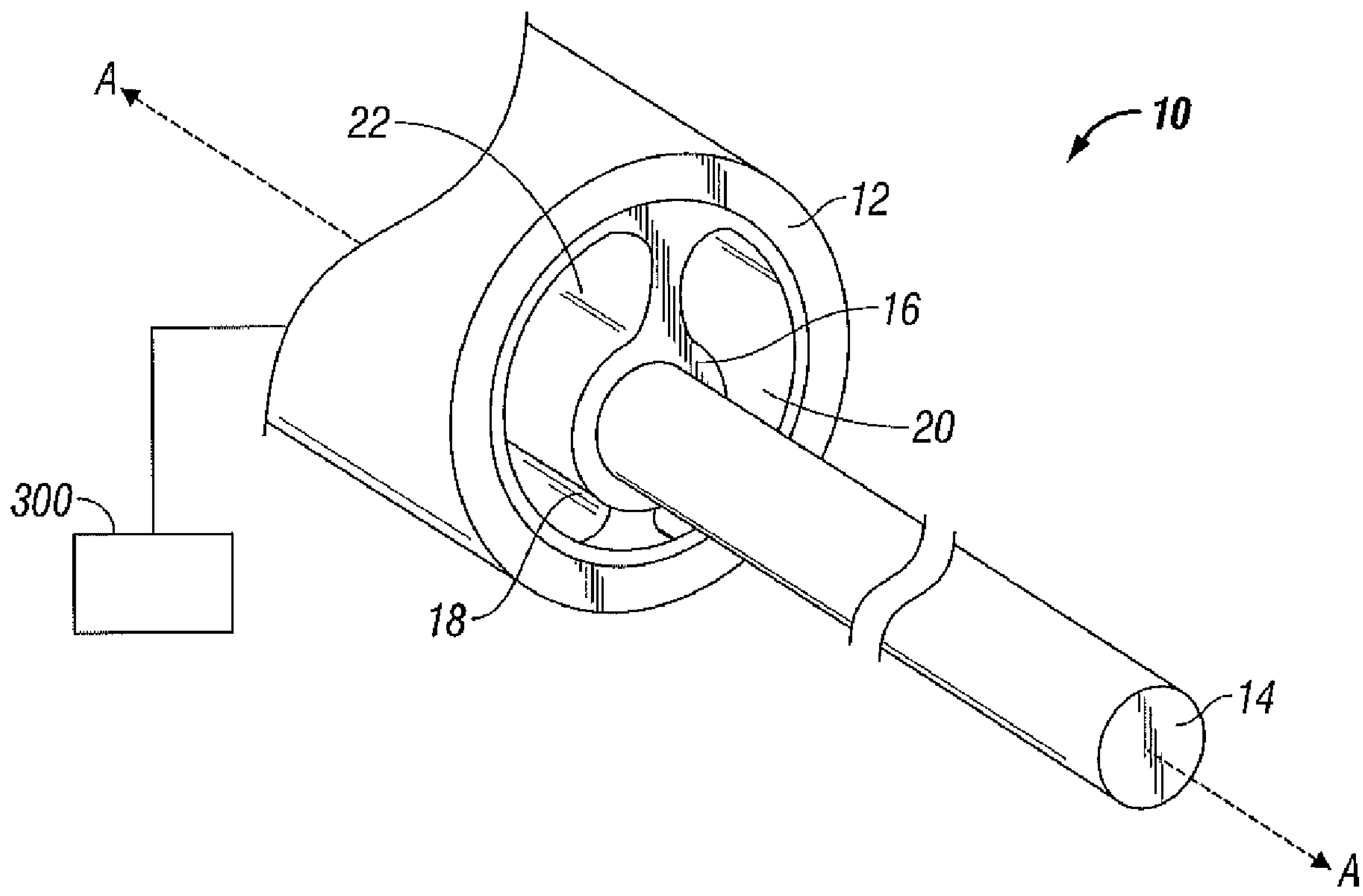

FIG. 1B

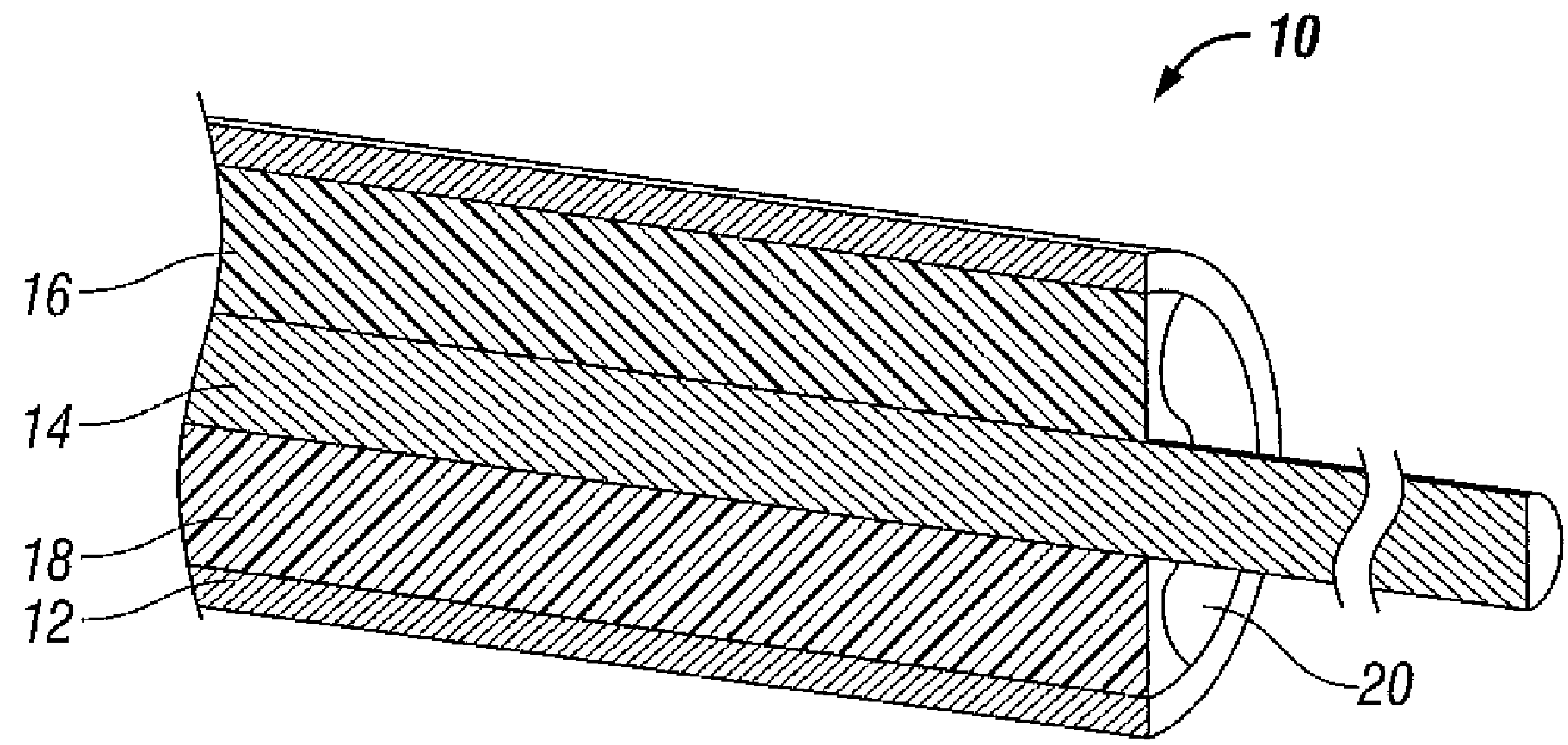

FIG. 1C

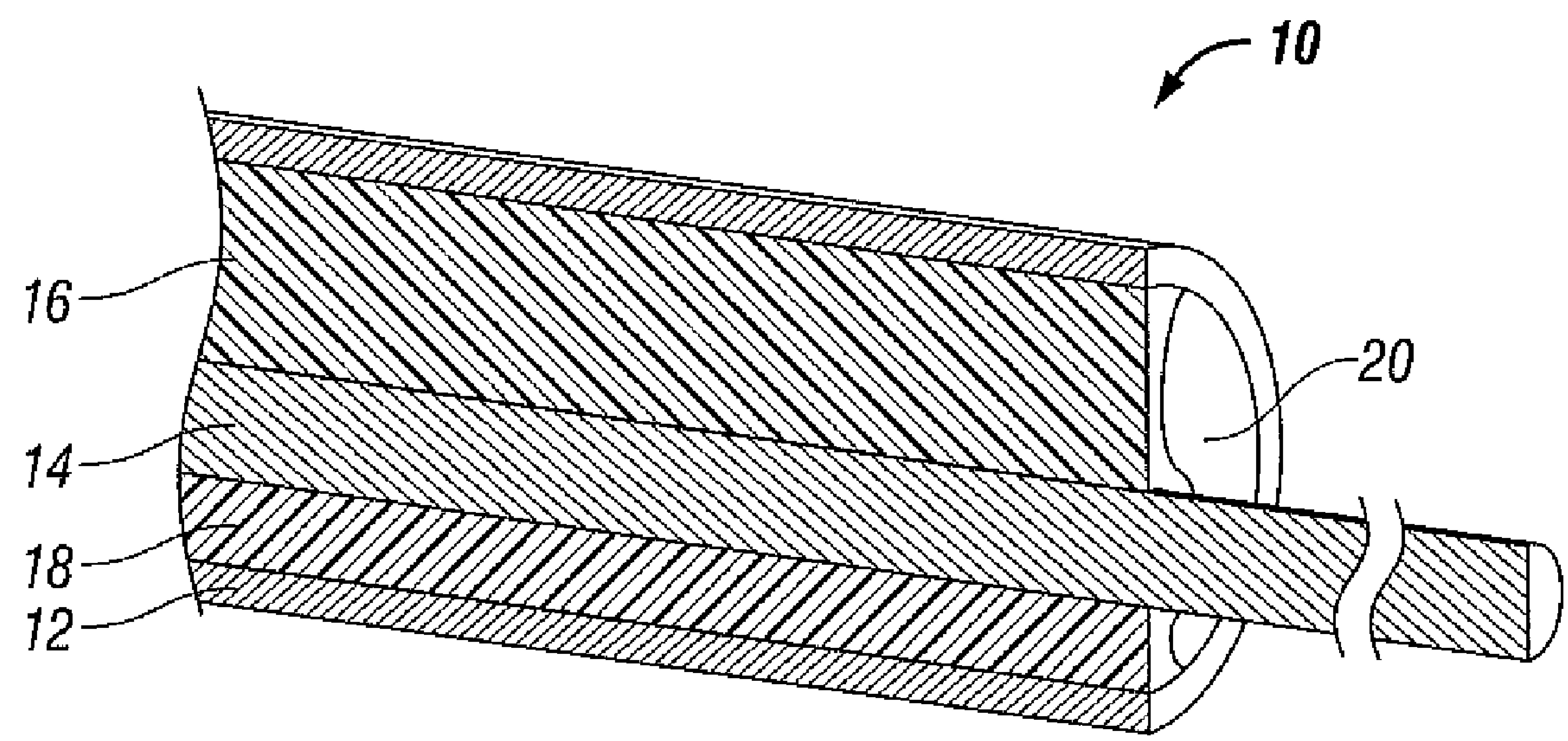

FIG. 1D

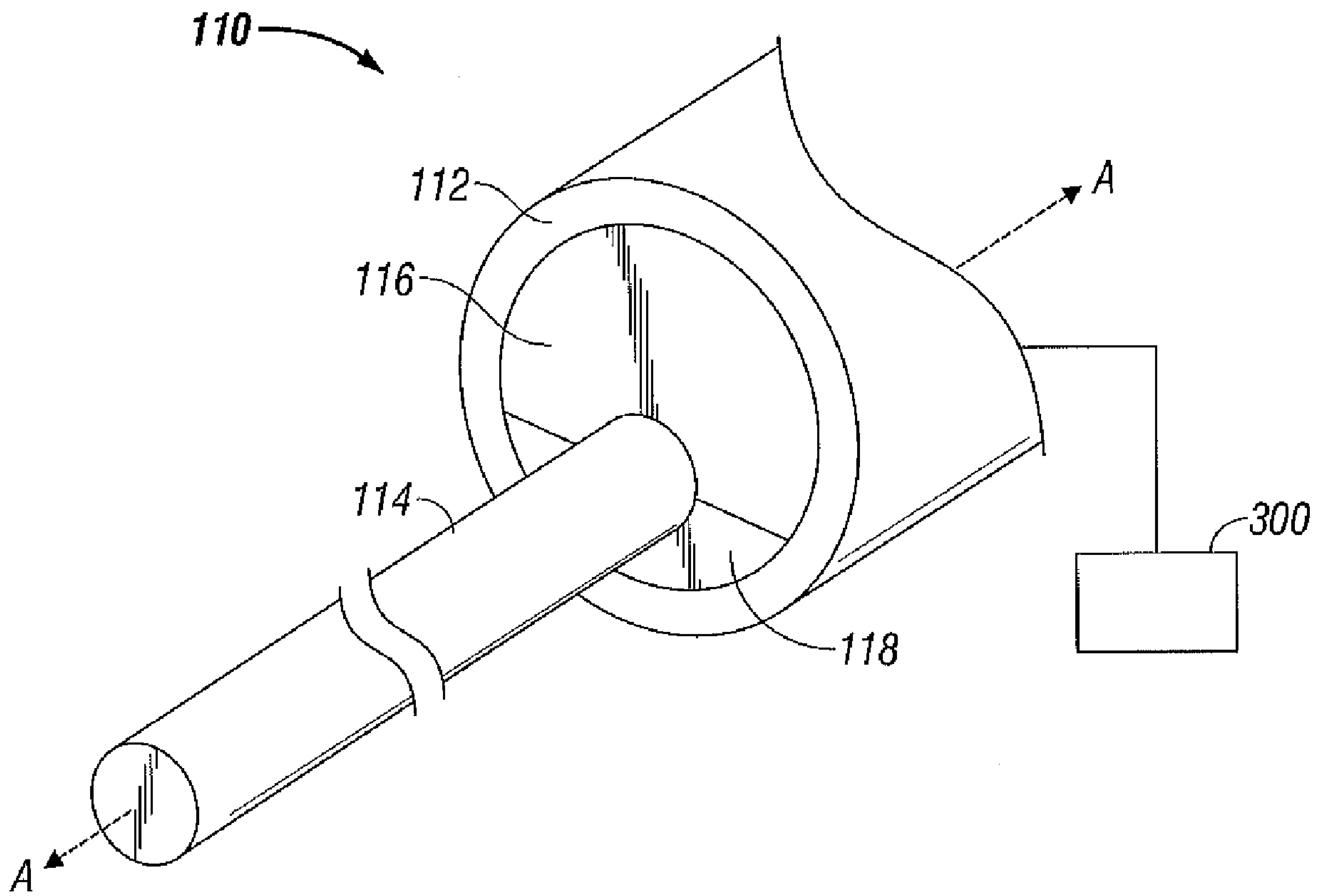

FIG. 2A

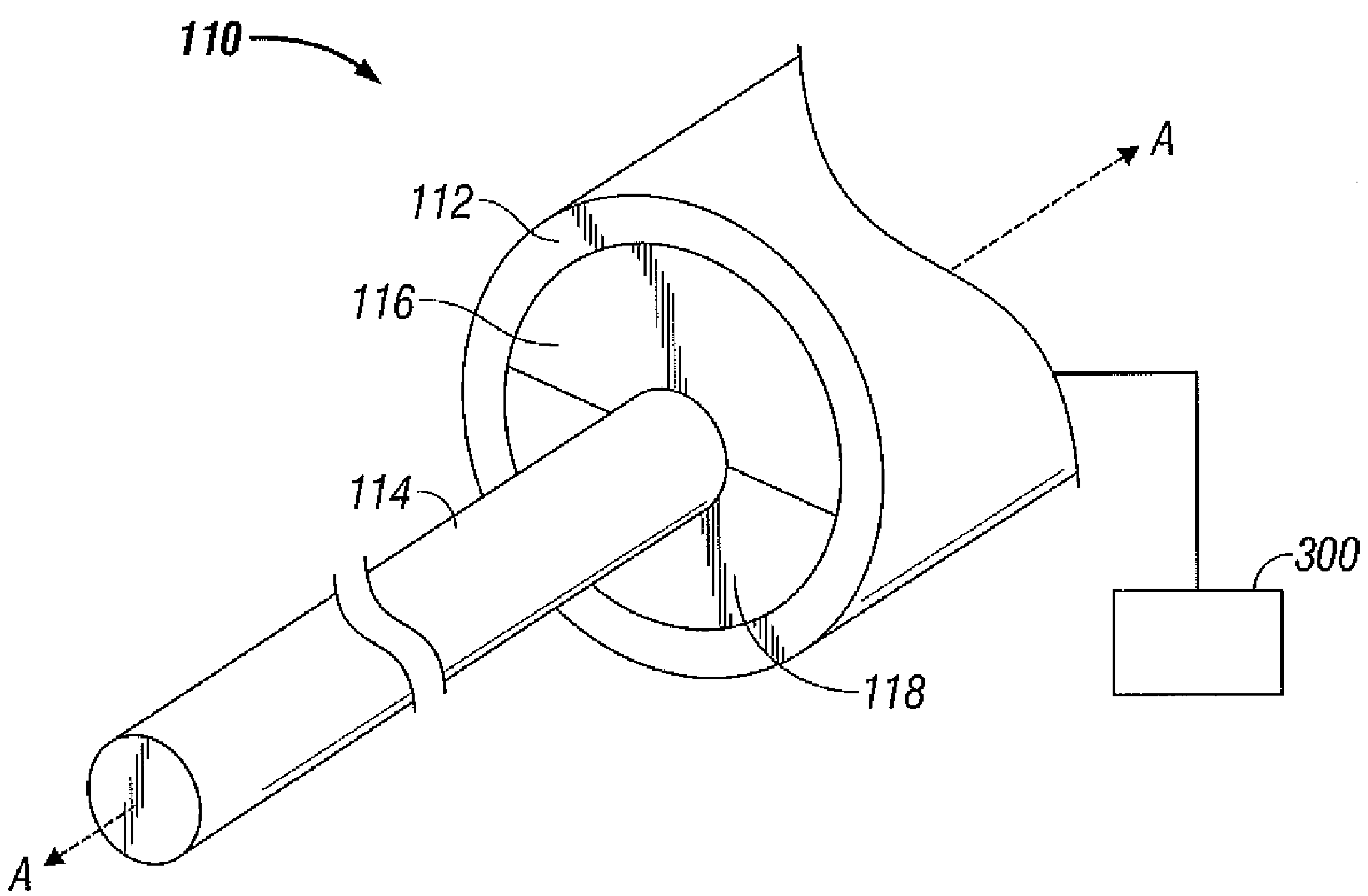

FIG. 2B

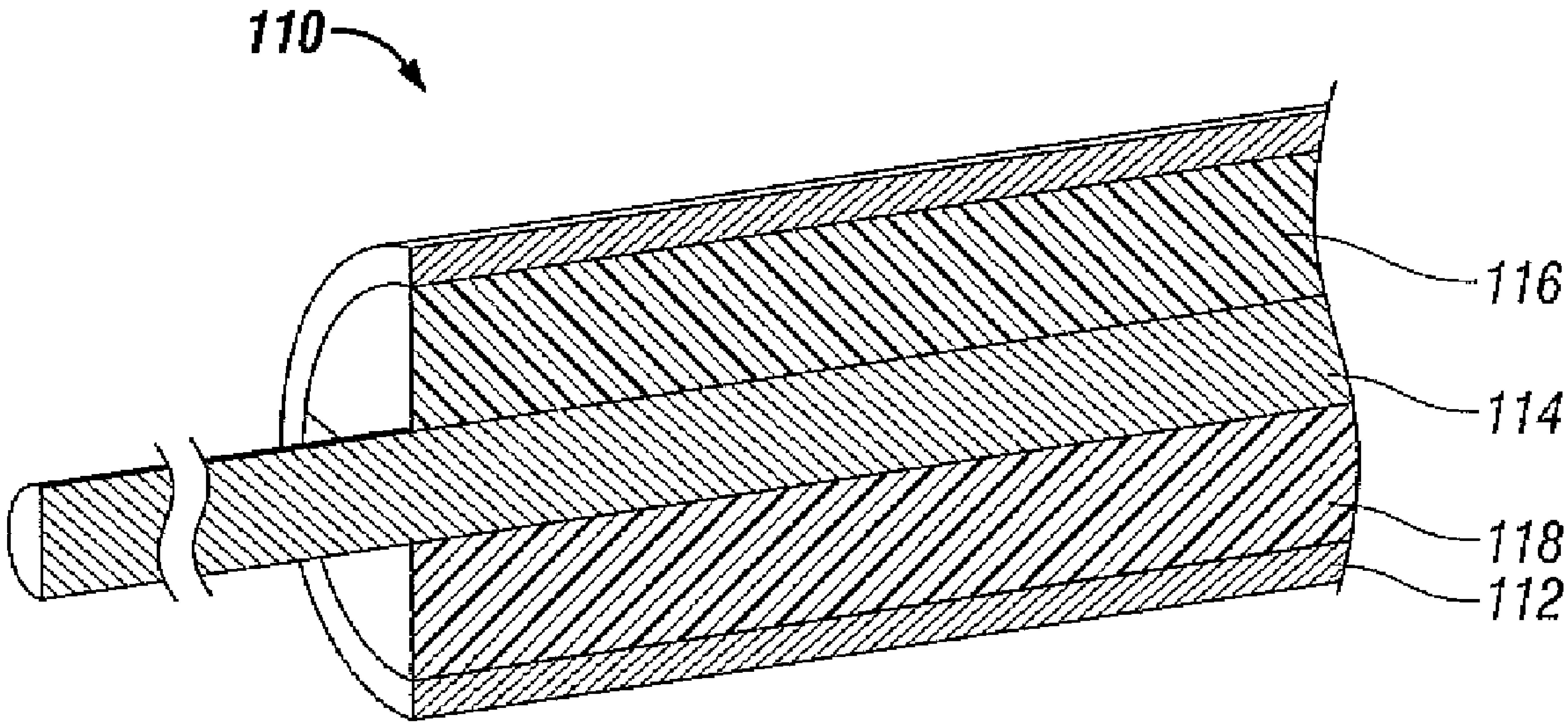

FIG. 2C

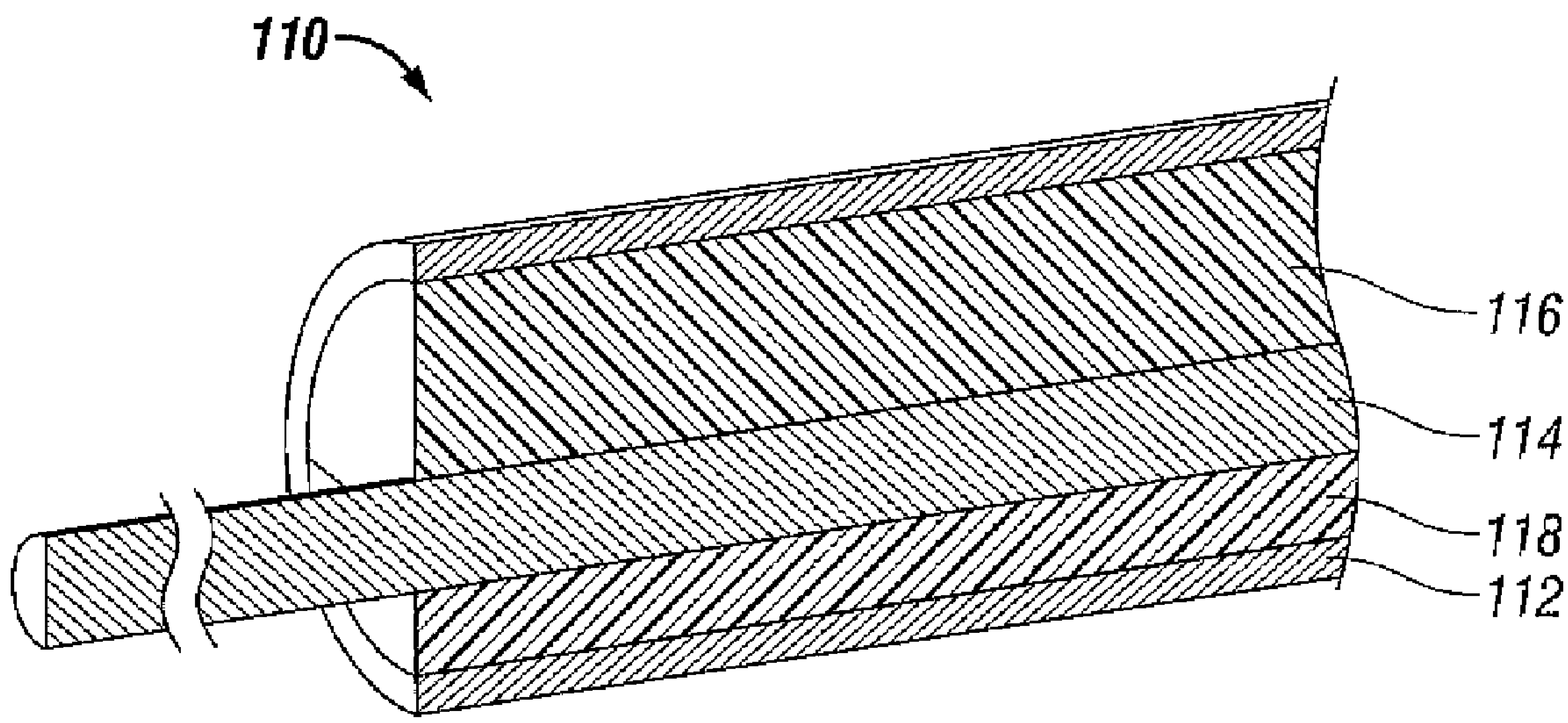

FIG. 2D

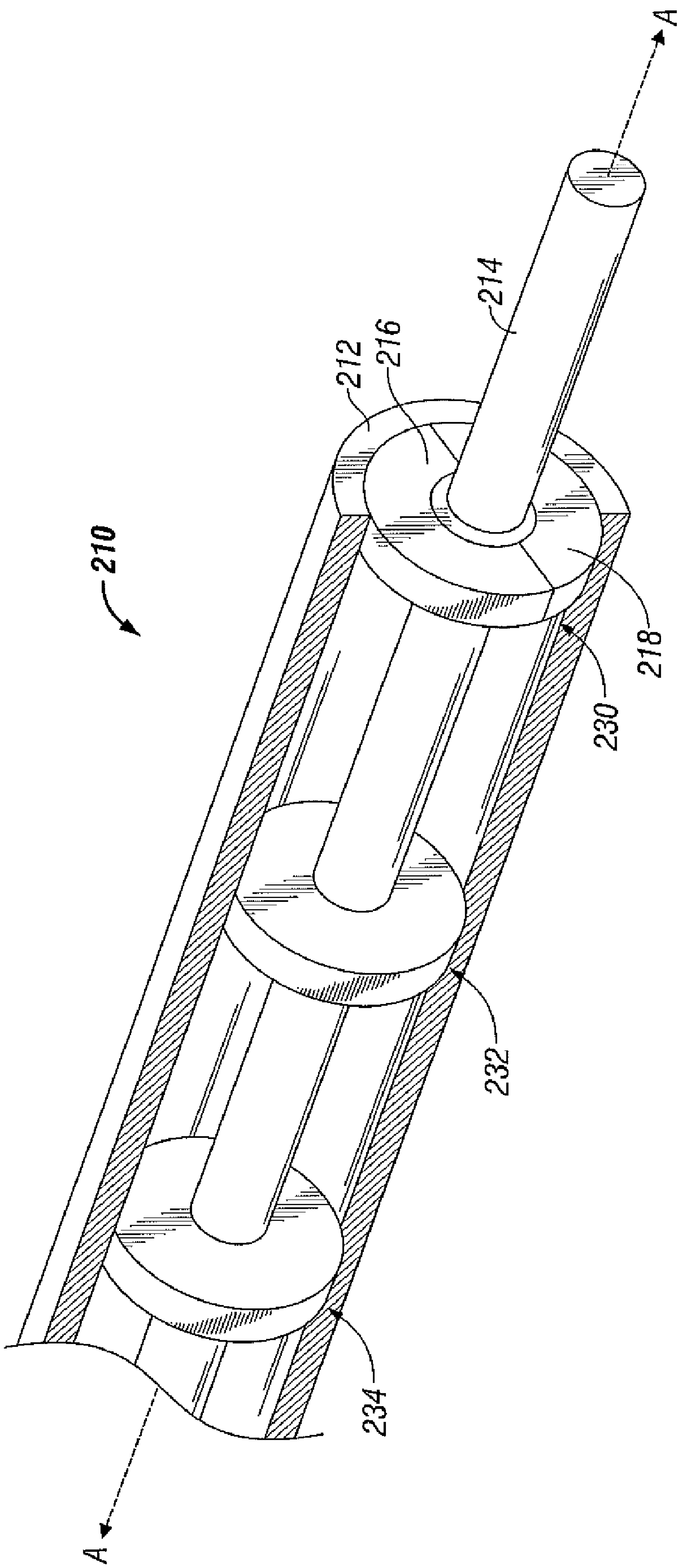

FIG. 3

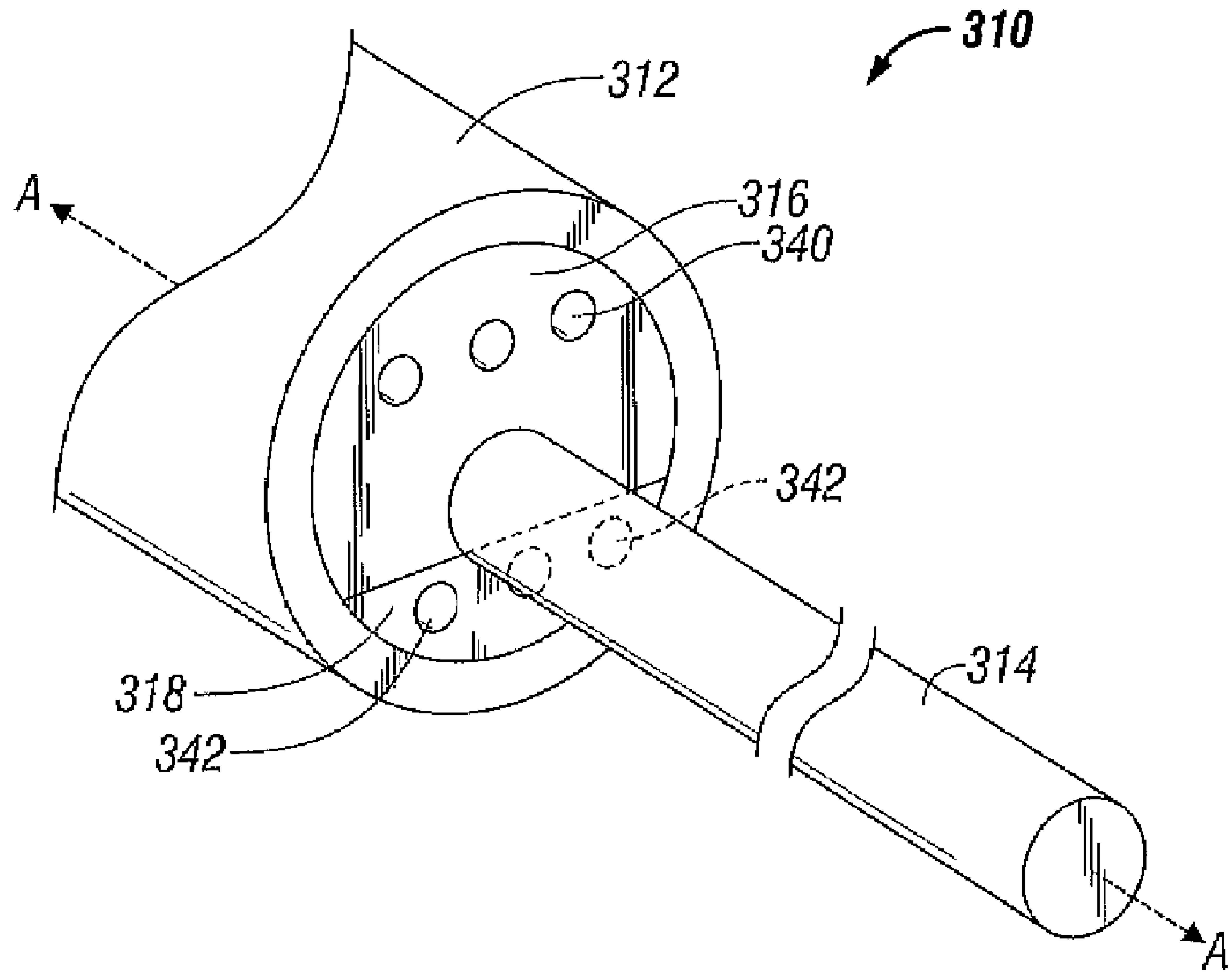

FIG. 4A

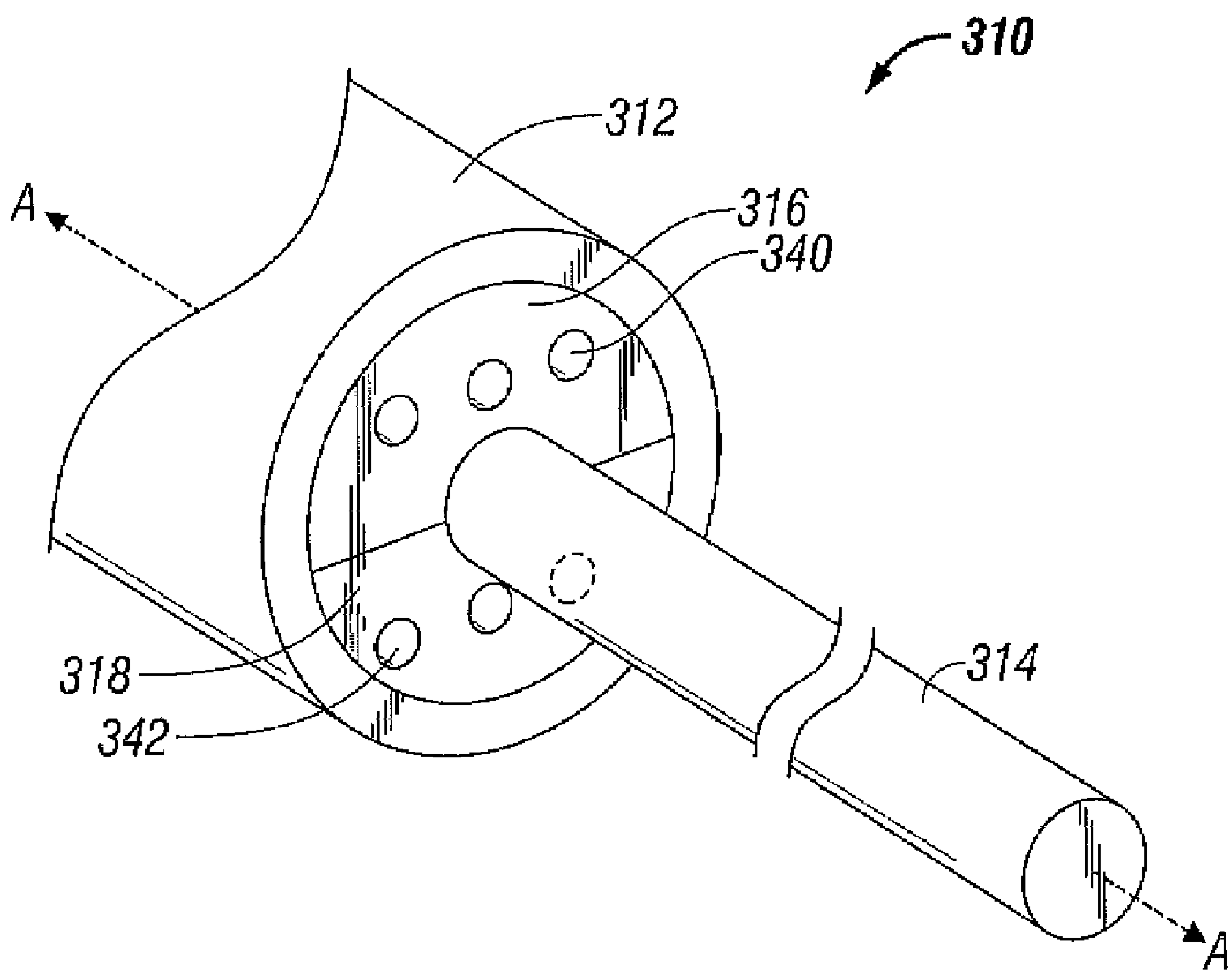

FIG. 4B

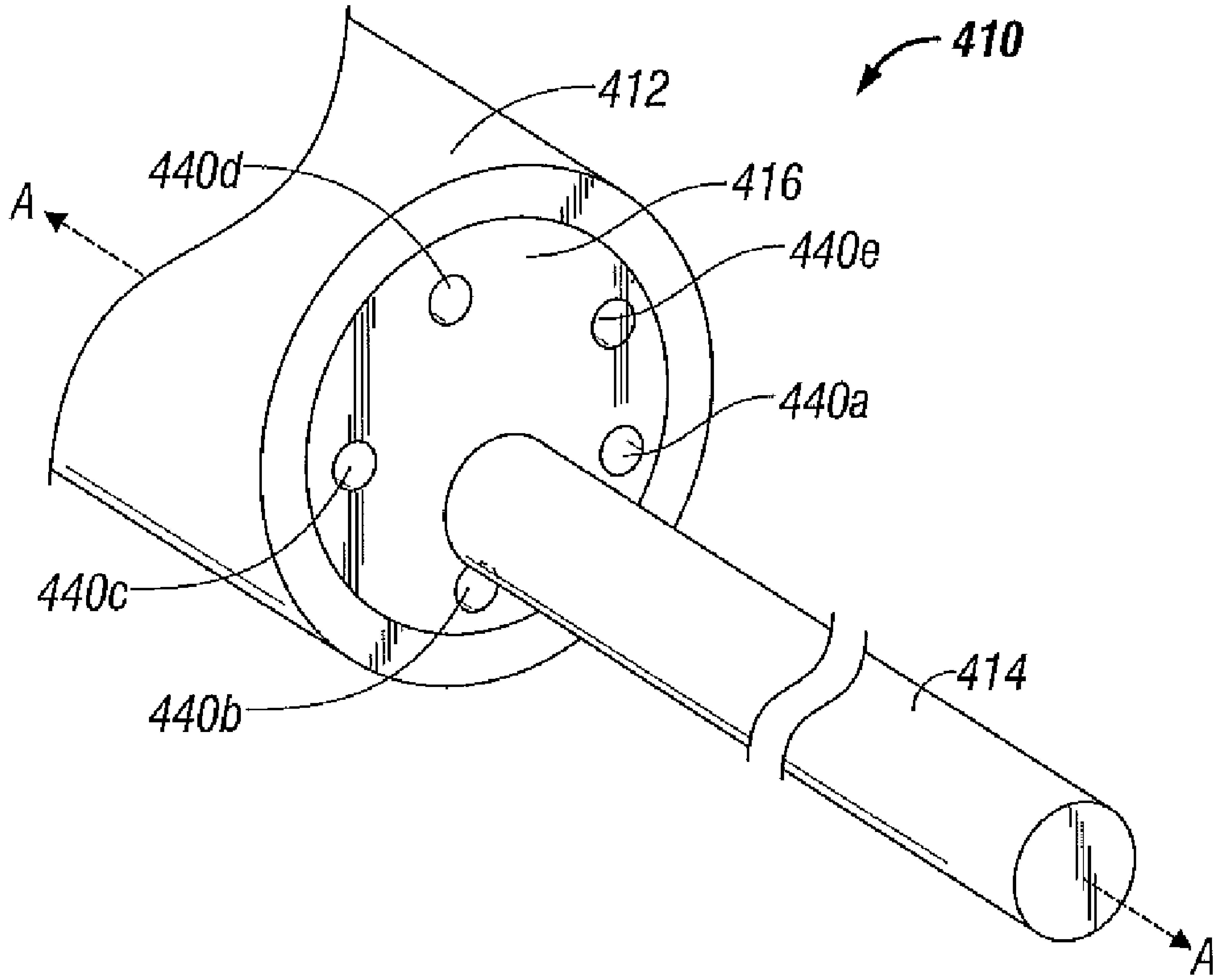
410
412
416
440d
440e
440a
440c
440b
414
A
A

FIG. 5A

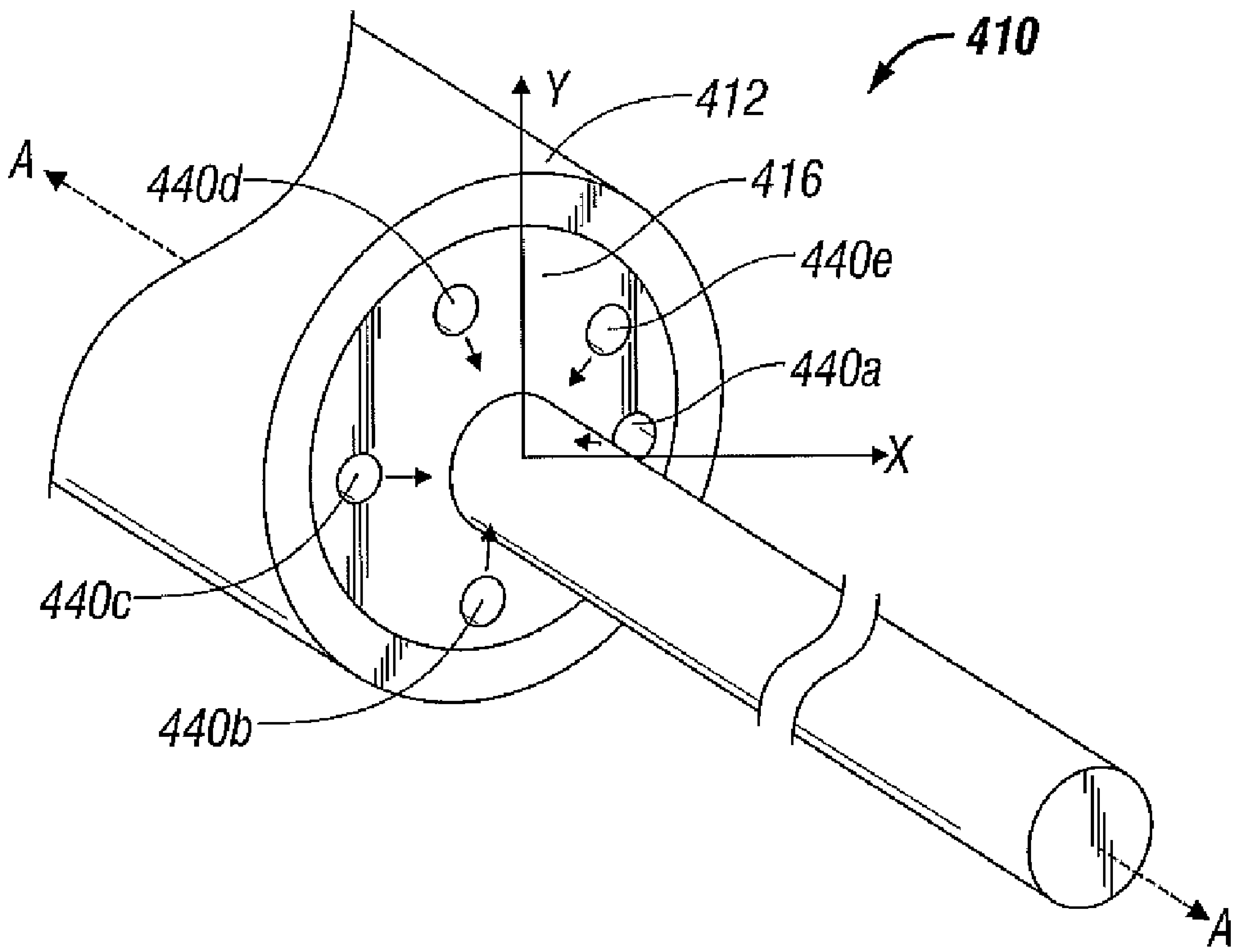
410
Y
412
416
440d
440e
440a
X
440c
440b
A
A

FIG. 5B

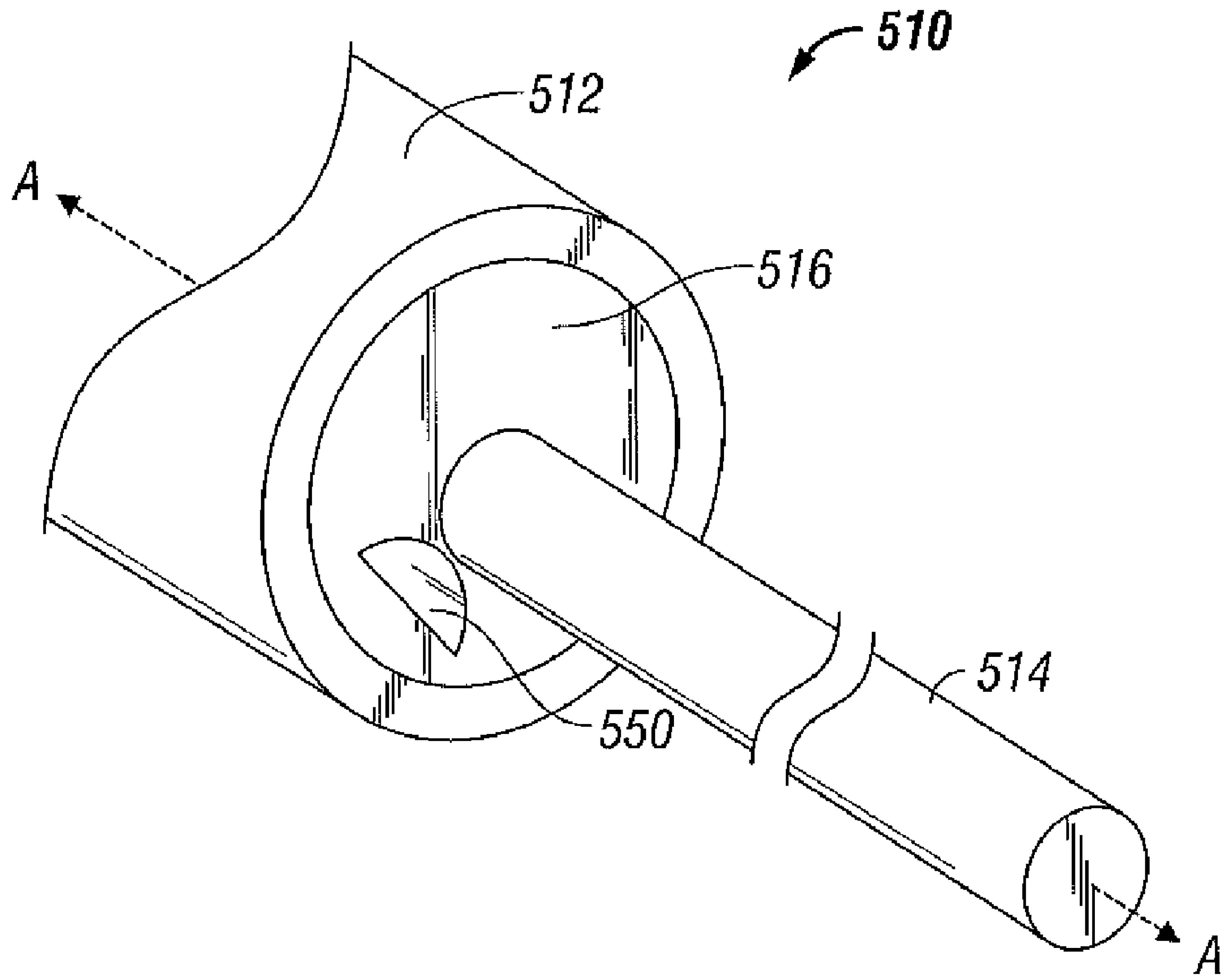
510
512
A
516
514
550
A

FIG. 6

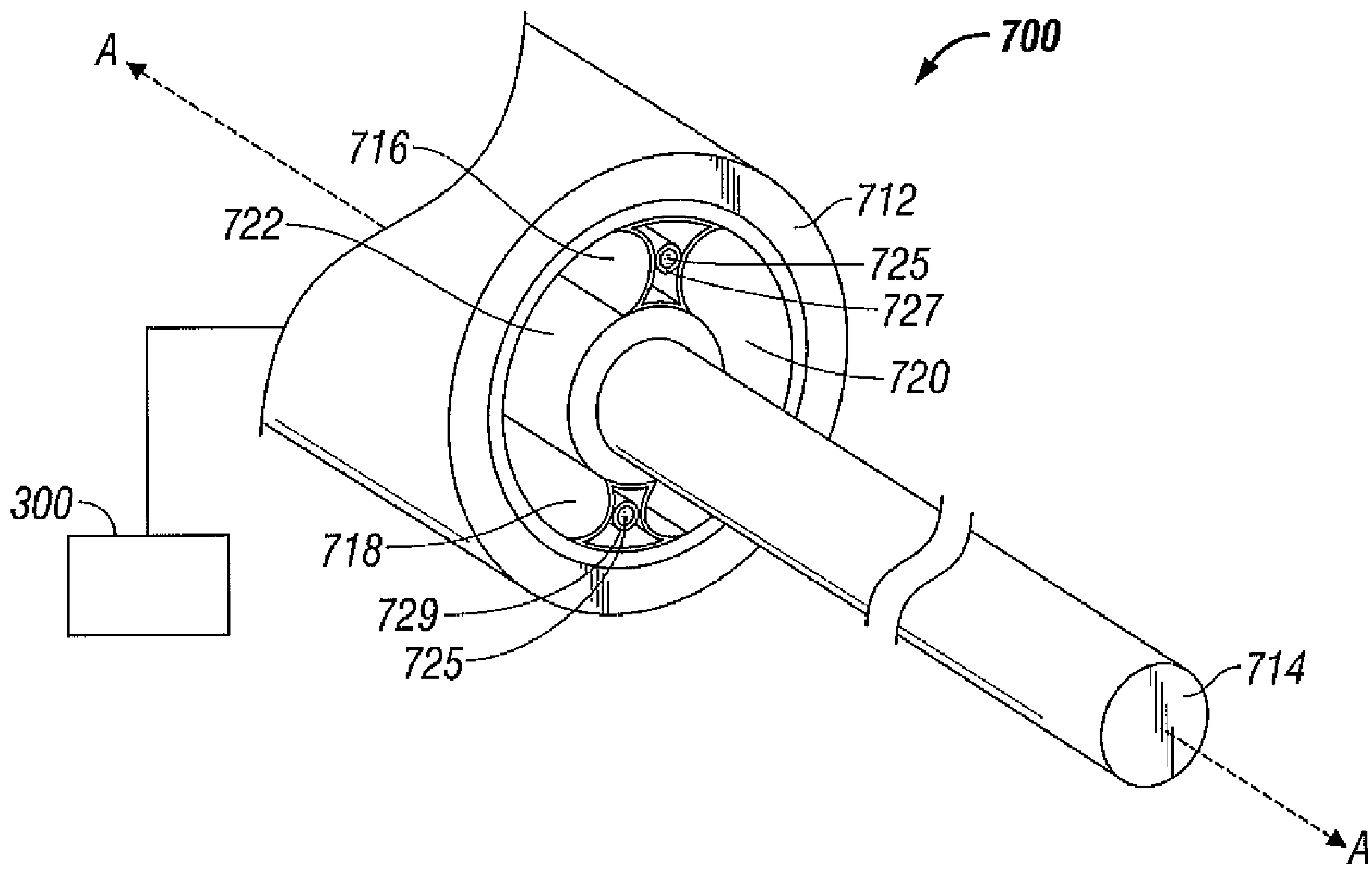
700
A
716
712
722
725
727
720
300
718
729
725
714
A

FIG. 7

THERMALLY TUNED COAXIAL CABLE FOR MICROWAVE ANTENNAS

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of priority to U.S. Provisional Patent Application Ser. No. 61/023,029, titled "THERMALLY TUNED COAXIAL CABLE FOR MICROWAVE ANTENNAS" filed Jan. 23, 2008 by Kenlyn Bonn, which is incorporated by reference herein.

BACKGROUND

1. Technical Field

The present disclosure relates generally to microwave antennas. More particularly, the present disclosure relates to thermally tuning coaxial cables for microwave antennas.

2. Background of Related Art

Microwave antennas are used in many applications. For example, medical microwave ablation antennas are used by surgeons. In fact, ablation devices utilizing DC shock, radio frequency (RF) current, ultrasound, microwave, direct heat, or lasers have been introduced and employed to various degrees to ablate biological tissues. Ablation devices may be used in open surgical procedures or are sometimes inserted into catheter devices in order to perform laparoscopic ablation procedures. The catheter incorporating the ablation device is generally inserted into a major vein or artery or through a body cavity. These catheters are then guided to a targeted location in the body (e.g., organ) by manipulating the catheter from the insertion point or the natural body orifice.

During ablation, the dielectric constant of the tissue changes as more water is boiled off and tissue desiccation occurs. The changing value of the dielectric constant alters the antenna's ability to match the originally designed impedance of the antenna. In addition, during microwave ablation in tissue, the impedance of the tissue varies during the course of ablation. This occurrence directly corresponds to how much energy has been deposited into the tissue during the ablation, resulting in temperature increases at the ablation site.

The impedance in the coaxial cable is typically related to the concentricity of the inner conductor in relationship to the outer conductor. In ablation procedures, however, conventional antenna designs only allow for an initial impedance match and as ablation occurs, the increase in mismatch between the tuning point of the antenna and the ablated tissue reduces the efficiency of the energy deposition in the tissue.

SUMMARY

The present disclosure relates to a coaxial cable. The coaxial cable includes an outer conductor and an inner conductor adapted to connect to an energy source for treating tissue, and first and second dielectric materials disposed between the inner conductor and the outer conductor which position the inner conductor relative to the outer conductor in general concentric relation thereto. The first dielectric material has a first coefficient of thermal expansion and the second dielectric material has a second coefficient of thermal expansion different from the first coefficient of thermal expansion.

In another embodiment, a coaxial cable also includes one or more dielectric spacer(s) disposed between the inner conductor and the outer conductor. The dielectric spacer(s) include first and second dielectric materials disposed between the inner conductor and the outer conductor, which position the inner conductor relative to the outer conductor in general concentric relation thereto. The first dielectric material has a first coefficient of thermal expansion and the second dielectric material has a second coefficient of thermal expansion different from the first coefficient of thermal expansion.

In an example embodiment, a heating element is disposed within the dielectric material and is adapted to connect to an energy source for controlling the temperature thereof. The heating element heats the dielectric material to cause thermal expansion thereof.

The present disclosure also relates to a method for controlling the impedance of coaxial cable used to treat tissue, the method includes the steps of: providing an outer conductor and an inner conductor adapted to connect to an energy source for treating tissue. The first and second dielectric materials are disposed between the inner conductor and the outer conductor and position the inner conductor relative to the outer conductor in general concentric relation thereto. The first dielectric material has a first coefficient of thermal expansion and the second dielectric material has a second coefficient of thermal expansion different from the first coefficient of thermal expansion. The method also includes the steps of energizing the cable and determining the impedance of the inner conductor, and regulating the change of impedance of the inner conductor by selectively heating at least one of the first and second dielectric materials causing thermal expansion thereof to move the inner conductor relative to the outer conductor to change the impedance of the coaxial cable.

Thus, by using dielectric cores of varying thermal expansion values, it is possible to force the eccentricity of the inner conductor of the coaxial cable on-line or off-line effectively changing the coaxial cable's impedance value.

BRIEF DESCRIPTION OF THE DRAWINGS

Various embodiments of the present disclosure are described herein with reference to the drawings wherein:

FIG. **1**A is a front, perspective view of a centrally-disposed coaxial cable having an inner conductor held by two materials having different coefficient of thermal expansion values, in accordance with an embodiment of the present disclosure;

FIG. **1**B is a front, perspective view of an off-center coaxial cable having an inner conductor held by two materials having different coefficient of thermal expansion values, in accordance with another embodiment of the present disclosure;

FIG. **1**C is a schematically-illustrated, cross-sectional view of the coaxial cable of FIG. **1**A;

FIG. **1**D is a schematically-illustrated, cross-sectional view of the coaxial cable of FIG. **1**B;

FIG. **2**A is front, perspective view of an off-centered coaxial cable having an inner conductor held by two materials having different coefficient of thermal expansion values, in accordance with another embodiment of the present disclosure;

FIG. **2**B is a front, perspective view of a centrally disposed coaxial cable having an inner conductor held by two materials having different coefficient of thermal expansion values, in accordance with another embodiment of the present disclosure;

FIG. **2**C is a schematically-illustrated, cross-sectional view of the coaxial cable of FIG. **2**B;

FIG. **2**D is a schematically-illustrated, cross-sectional view of the coaxial cable of FIG. **2**A;

FIG. **3** is a schematically illustrated, cross-sectional view of a coaxial cable having an inner conductor held by one or more spacers being composed of one or more materials having different coefficient of thermal expansion values, in accordance with another embodiment of the present disclosure;

FIG. **4**A is a front, perspective view of an off-centered coaxial cable having an inner conductor and a plurality of resistive heating elements in each of two or more materials having different coefficient of thermal expansion values, in accordance with another embodiment of the present disclosure;

FIG. **4**B is a front, perspective view of a centrally disposed coaxial cable having an inner conductor and a plurality of resistive heating elements in each of two or more materials having different coefficient of thermal expansion values, in accordance with another embodiment of the present disclosure;

FIG. **5**A is a schematically illustrated cross-sectional view of an off-centered coaxial cable having an inner conductor and a plurality of resistive heating elements in one material having one coefficient of thermal expansion value, in accordance with another embodiment of the present disclosure;

FIG. **5**B is a front, perspective view of a centrally disposed coaxial cable having an inner conductor and a plurality of resistive heating elements in one material having one coefficient of thermal expansion value, in accordance with another embodiment of the present disclosure;

FIG. **6** is a front, perspective view of a coaxial cable having an inner conductor with a shape memory alloy, in accordance with another embodiment of the present disclosure; and

FIG. **7** is a front, perspective view of a centrally-disposed coaxial cable having an inner conductor held by two materials having different coefficient of thermal expansion values with a fluid circulated therethrough for regulating the thermal expansion of the two materials in accordance with another embodiment of the present disclosure.

DETAILED DESCRIPTION

To achieve the foregoing and other objects of the present disclosure, methods and devices pertaining to the microwave antennas are disclosed. In general, the present disclosure pertains to a coaxial cable assembly and, in one embodiment, to a surgical device including the coaxial cable assembly. The surgical device generally includes an ablative energy source and an ablative energy delivery device coupled to the ablative energy source. The ablative energy delivery device is configured to deliver ablative energy sufficiently strong enough to cause tissue ablation. In most embodiments, the ablative energy is formed from electromagnetic energy in the microwave frequency range. Other applications are contemplated by the present disclosure, such as telecommunications or other suitable applications in which microwave antennas are utilized.

Particular embodiments of the present disclosure are described hereinbelow with reference to the accompanying drawings. In the following description, well-known functions or constructions are not described in detail to avoid obscuring the present disclosure in unnecessary detail. Those skilled in the art will understand that the present disclosure may be adapted for use with either an endoscopic instrument or an open instrument.

While the present disclosure is susceptible to embodiments in many different forms, there is shown in the drawings and will be described herein in detail one or more embodiments of the present disclosure. However, the present disclosure is to be considered an exemplification of the principles of the present disclosure, and the embodiment(s) illustrated is/are not intended to limit the spirit and scope of the present disclosure and/or the claims herein.

With reference to the drawings, the coaxial cable of the particular embodiments of the present disclosure are shown. The cable may be of any suitable length, and the figures are not intended to limit the length of the cable to a specific length illustrated or any specific length. Instead, only a representative portion or section of cable is illustrated.

Referring to the embodiment of FIGS. **1**A and **1**B, the coaxial cable **10** includes an outer conductor **12**, an inner conductor **14**, a first material **16**, a second material **18**, a first air gap **20**, and a second air gap **22**. The inner conductor **14** is connected to an external power source **300**.

The coaxial cable **10** may be rigid, rigid-but shapeable or flexible. The coaxial cable **10** may be chosen from commercially available standards and is generally designed with a characteristic impedance of 50 Ohms. In addition, one side of the coaxial cable **10** may be coupled to a power supply **300**. Also, the other side of the coaxial cable **10** may be coupled to an antenna (not shown) in any suitable manner.

The outer conductor **12** is arranged to be generally concentric with respect to the inner conductor **14**. However, the concentric relationship may be configured to meet a particular purpose as explained in more detail below. Inner conductor **14** is a central conductor used for transmitting signals and is typically held relative to the outer conductor **12** by first material **16** and second material **18**. In one embodiment, the first material **16** holds the inner conductor **14**, whereas the second material **18** supports the first material **16** without contacting the inner conductor **14**. In other words, only one material contacts the inner conductor **14**.

In the illustrated embodiment, the first material **16** and the second material **18** define first and second air gaps **20**, **22** between the inner surface of the outer conductor **12** and the outer surface of the inner conductor **14**. The first air gap **20** separates a first portion of the first material **16** and a first portion of the second material **18**. The second air gap **22** separates a second portion of the first material **16** with a second portion of the second material **18**.

The inner conductor **14** has a significant effect on the coaxial cable's **10** properties, such as the cable's **10** impedance and attenuation characteristics. The impedance on the coaxial cable **10** is related to the concentricity of the inner conductor **14** in relationship to the outer conductor **12**. In the first embodiment, a thermal increase to the coaxial cable **10** is used to alter the alignment concentricity of the inner conductor **14** in a manner that would better match a change in tissue impedance. The coaxial cable **10** in the antenna (not shown) would start with an initial impedance match to a transmission line interface that would gradually taper along the length of the antenna toward a desired impedance with either the addition or the subtraction of heat. The taper could be controlled thermally through additional features, such as a cooling jacket or cooling channels.

FIGS. **1**A and **1**C illustrate the inner conductor **14** in a centered position within the coaxial cable **10**. As heat is applied, the inner conductor **14** is moved to an off-centered position due to the thermal expansion of material **18**, as shown in FIGS. **1**B and **1**D. As the tissue impedance changes, the alignment sensitivity of the cable **10** may be selectively changed (e.g., automatically or manually) such that the impedance of the cable **10** better matches the tissue impedance. One or more materials with different coefficients of thermal expansion may be utilized which mutually cooperate to tune the inner conductor **14** according to a desired setting, such as an ohmage setting.

FIGS. **2**A and **2**D show an off-centered coaxial cable **110** and FIGS. **2**B and **2**C show a centrally disposed coaxial cable **110** having an inner conductor held by two materials having different coefficient of thermal expansion values. The coaxial cable **110** includes an outer conductor **112**, an inner conductor **114**, a first material **116** and a second material **118**. The inner conductor **114** is connected to an external power source **300**.

The first material **116** has a first coefficient of thermal expansion value and the second material **118** has a second coefficient of thermal expansion value, the first and second coefficient of thermal expansion values being different. During heat transfer, the energy that is stored in the intermolecular bonds between atoms changes. When the stored energy increases, so does the length of the molecular bond. As a result, materials typically expand in response to heating and contract on cooling. This response to temperature change is expressed as the materials coefficient of thermal expansion. The coefficient of thermal expansion is used in two ways: (1) as a volumetric thermal expansion coefficient and (2) as a linear thermal expansion coefficient.

Therefore, when the temperature applied to the coaxial cable **110** changes, the first material **116** expands at a first rate/volume and the second material **118** expands at a second rate/volume. Typical materials used in coaxial cables include variations of PTFE, polyethylene (PE) blends and silica dioxides, however, nearly any thermo-set or thermoplastic with a low dielectric constant can be used in conjunction with another material of similar dielectric constant with a different coefficient of thermo-expansion. Typically, different polymer grades or blends result in varying material properties so determining the desired pair of materials would be a result of finding a matching mixture. The heat generated by the losses in the dielectric material in the cable can also be utilized to heat material enough to generate the differential in thermal expansion between the varying materials. A variety of different materials with different coefficient of thermal expansion values may be utilized, e.g., ABS Polymer Extruded, ABS Polymer Nylon Blend, PEEK Polyketone, PEKK Polyketone, Nylon PTFE Filled, Polycarbonate Extruded, LDPE (Polyethylene), Polyimide, PTFE Molded, Silica Aerogel and combinations thereof.

If the first material **116** expands due to a temperature increase, the second material **118** contracts due to the differing coefficient of thermal expansion values of the two materials **116**, **118**. As a result, as the ablation zone heats up, the difference in expansion between the two materials **116**, **118** would cause the inner conductor **114** to change alignment with the outer conductor **112**, e.g., move toward a centered position as illustrated in FIGS. **2**B and **2**C.

As can be appreciated, the materials **116**, **118** may be designed to selectively (e.g., either automatically or manually) align or misalign the inner conductor **114** relative to the outer conductor **112** for tuning and impedance matching purposes. In the embodiment, as seen in FIGS. **1**A and **1**B, the design could be made to start with the inner conductor **114** concentrically centered relative to outer conductor **112** and then moved off center when the temperature changes. As shown in FIGS. **2**A and **2**B, inner conductor **114** may be normally off-center relative to outer conductor **112**, and as the temperature increases, the inner conductor **114** moves toward the concentric center of the coaxial cable **110** when one of the materials **116**, **118** is heated.

The system described in regard to FIGS. **1**A-**2**B may include an electrosurgical generator **300** having a microprocessor and sensor circuitry (not shown) that continually monitors tissue impedance and measures offset impedance. The sensor circuitry may also continually monitor the position of the inner conductor **114** of a coaxial cable **110** with respect to a desired coaxial position (e.g., a center position). The monitor may be operably coupled to a mechanism (shape memory alloy, heat resistive element) as explained in more detail below) for regulating the thermal expansion of at least one of the first and second dielectric materials **116**, **118** to position the inner conductor **114** relative to the outer conductor **112** to change the impedance of the inner conductor **114**. The microprocessor or the circuitry may also be configured to compare the inner conductor positioning to a predetermined center position. If the inner conductor is positioned above or below the predetermined center position, one or more materials **116**, **118** surrounding the inner conductor are heated or moved to re-position the inner conductor **114** to a desired position, and the microprocessor reports such findings to a user control or maintains this data for subsequent use.

FIG. **3** is a schematically illustrated cross-sectional view of a coaxial cable **210** having an inner conductor **214** held by one or more spacers **230**, **232**, **234** being composed of one or more materials having different coefficient of thermal expansion values. In FIG. **3**, the coaxial cable **210** includes an outer conductor **212**, an inner conductor **214**, a first material **216**, a second material **218**, a first spacer **230**, a second spacer **232** and a third spacer **234**. The inner conductor **214** is connected to an external power source **300**.

The first, second, and third spacers **230**, **232**, **234** maintain a desired position (e.g., a center position) for the inner conductor **214** for at least a partial length of the coaxial cable **210**. Each of the spacers **230**, **232**, **234** may have the same or a different width, and each may be composed of one material or two or more materials. Also, the material used for each spacer may be different. For example, a first spacer **230** may be composed of a first material **216** and a second material **218**, whereas the second and third spacers **232**, **234** may be composed of one material.

FIG. **4**A is a schematically illustrated cross-sectional view of an off-centered coaxial cable **310** and FIG. **4**B is a schematically illustrated cross-sectional view of a centrally disposed coaxial cable **310** having an inner conductor and a plurality of resistive heating elements in each of two or more materials having different coefficient of thermal expansion values. In FIGS. **4**A and **4**B, the coaxial cable **310** includes an outer conductor **312**, an inner conductor **314**, a first material **316**, a second material **318**, first resistive heating elements **340** and second resistive heating elements **342**.

FIG. **4**A illustrates the inner conductor **314** in an off-centered position within the coaxial cable **310**. As heat is applied via the heating resistive elements **340**, **342** shown in FIG. **4**B, the inner conductor **314** moves to a centered position due to the thermal expansion of material **318**. As the tissue impedance changes, the alignment sensitivity of the cable **310** may be selectively changed (e.g., automatically or manually) such that the impedance of the cable **310** better matches the tissue impedance. One or more materials may be utilized to tune the inner conductor **314** according to a desired setting, such as an ohmage setting.

A plurality of first resistive heating elements **340** may be positioned in first material **316** and a plurality of second resistive heating elements **342** may be positioned in second material **318**. The first and second resistive heating elements **340**, **342** convert electricity into heat. Electrical current running through the elements encounter resistance, thus resulting in heating of the element. Resistive heating elements **340**, **342** may be made from Nichrome which has a relatively high resistance and does not break down or oxidize in air at useful temperature ranges. First and second resistive heating elements **340**, **342** may also be positioned in parallel to the inner conductor **314**, at various lengths from the inner conductor **314**, and in various widths. The temperature of each of the plurality of heating elements **340**, **342** may be selectively controllable to position the inner conductor **314** relative to the outer conductor **312** and the plurality of heating elements **340**, **342** may be disposed in a concentric array relative to the inner conductor **314**.

FIG. **5**A is a schematically illustrated cross-sectional view of an off-centered coaxial cable **410** and FIG. **5**B is a schematically illustrated cross-sectional view of a centrally disposed coaxial cable **410**. In FIGS. **5**A and **5**B, the coaxial cable **410** includes an outer conductor **412**, an inner conductor **414**, a dielectric material **416**, and one or more resistive heating elements **440**. In contrast to FIGS. **4**A and **4**B, only one dielectric material **416** is used to surround the entire length of the inner conductor **414**. The dielectric material **416** includes one or more resistive heating elements **440** in parallel to the inner conductor **414** along the length of the cable **410**. More particularly, the resistive heating elements **440** are positioned in parallel to the inner conductor **414**, at various lengths along the inner conductor **414**, and in various widths.

FIG. **5**A illustrates the inner conductor **414** in an off-centered position within the dielectric material **416**. As heat is applied, the inner conductor **414** is moved to a desired position (e.g., a center position) due to the thermal expansion of dielectric material **416** and due to first resistive heating element **440***b* being heated to expand the dielectric material **416** in a given direction. Any member or combination of heating elements **440***a*-**440***e* may be utilized to move the inner conductor **414** for tuning purposes. As the tissue impedance changes, the alignment sensitivity of the cable **410** may be selectively changed (e.g., automatically or manually) such that the impedance of the cable **410** better matches the tissue impedance.

FIG. **6** is a schematically illustrated cross-sectional view of a coaxial cable having an inner conductor with a shape memory alloy **550** in accordance with another embodiment of the present disclosure. In FIG. **6**, the coaxial cable **510** includes an outer conductor **512**, an inner conductor **514**, a dielectric material **516** and a shape memory alloy **550**.

The shape memory alloy **550** is, for example, positioned in proximity to the inner conductor **514**. One or more shape memory alloys **550** may be positioned along the length of the coaxial cable **510** in predetermined distance from each other.

Shape memory alloys (SMAs) are a family of alloys having anthropomorphic qualities of memory and trainability and are particularly well suited for use with medical instruments. SMAs have been applied to such items as actuators for control systems, steerable catheters and clamps. One of the most common SMAs is Nitinol which can retain shape memories for two different physical configurations and changes shape as a function of temperature. Recently, other SMAs have been developed based on copper, zinc and aluminum and have similar shape memory retaining features.

SMAs undergo a crystalline phase transition upon applied temperature and/or stress variations. A particularly useful attribute of SMAs is that after it is deformed by temperature/stress, it can completely recover its original shape on being returned to the original temperature. The ability of an alloy to possess shape memory is a result of the fact that the alloy undergoes a reversible transformation from an austenitic state to a martenistic state with a change in temperature/stress. This transformation is referred to as a thermoelastic martenistic transformation.

Under normal conditions, the thermoelastic martenistic transformation occurs over a temperature range which varies with the composition of the alloy, itself, and the type of thermal-mechanical processing by which it was manufactured. In other words, the temperature at which a shape is "memorized" by an SMA is a function of the temperature at which the martensite and austenite crystals form in that particular alloy. For example, Nitinol alloys can be fabricated so that the shape memory effect will occur over a wide range of temperatures, e.g., −270° to +100° Celsius. Many SMAs are also known to display stress-induced martenisite (SIM) which occurs when the alloy is deformed from its original austensitic state to a martensitic state by subjecting the alloy to a stress condition.

As a result, when heat is applied to the coaxial cable **510**, the inner conductor **514** tends to move from its desired position within the coaxial cable **510**. SMA **550**, which is embedded within a material **516** having a certain coefficient of thermal expansion and which is located in a close proximity to the inner conductor **514** may move the inner conductor **514** back to its desired position (e.g., a center position) within the coaxial cable **510**. SMA **550** can recover from large amounts of bending and torsional deformations, due to the application of heat, as well as small amounts of strain. Provided the deformations are within recoverable ranges, the process of deformation and shape recovery can be repeated millions of times. As a result, the SMA **550** located within the material **516** can repeatedly move the inner conductor **514** back to a desired position (e.g., a centered position). Moreover, as can be appreciated, the material **516** may be designed to selectively (e.g., either automatically or manually) align or misalign the inner conductor **514** relative to the outer conductor **512** for tuning and impedance matching purposes.

Consequently, the embodiments of the present disclosure allow for improved antenna impedance matching for controlling tissue impedance of a microwave antenna during an ablation procedure via a thermally tuned coaxial cable. The embodiments further include changing the impedance of the coaxial cable for allowing greater flexibility in designing microwave antennas. By having a varying impedance of the coaxial cable in the antenna tuned to change with the increase/decrease in temperature, tissue impedance changes, and thus, the antenna may deposit a greater amount of energy over the entire course of the ablation procedure. By using dielectric cores of varying thermal expansion values, it is possible to force the eccentricity of the inner conductor of the coaxial cable on-line or off-line, thus effectively changing the coaxial cable's impedance value.

In addition, FIGS. **1**A-**2**D illustrate two materials **16**, **18** within the spacing between the inner surface of the outer conductor **12** and the outer surface of the inner conductor **14** including two air spaces or gaps **20**, **22**. However, one skilled in the art may use more than two materials within the spacing between the inner surface of the outer conductor **12** and the outer surface of the inner conductor **14** and more than two air gaps. For example, one skilled in the art may be motivated to use three or more materials, each with a different coefficient of thermal expansion value in a triangular configuration with three or more air gaps separating the materials. In addition, one skilled in the art may be motivated to use two materials in a checkered pattern or any other type of intertwined pattern with one or more air gaps in order to center or off-center the inner conductor **14** of the coaxial cable **10** as needed to tune or match the tissue impedance.

Further, in FIGS. **1**A-**6** there may be one or more mechanisms that regulate the thermal expansion of at least one of the first and second dielectric materials **16**, **18** to position the inner conductor **14** relative to the outer conductor **12** to change the impedance of the inner conductor **14**.

FIG. **7** shows another embodiment according to the present disclosure wherein the coaxial cable **700** includes an outer conductor **712** arranged to be generally concentric with respect to the inner conductor **714** used for transmitting signals. Inner conductor **714** is held relative to the outer conductor **712** by first material **716** and second material **718** only one of which contacts inner conductor **714**. First material **716** and the second material **718** define first and second air gaps **720** and **722**, respectively, between the inner surface of the outer conductor **712** and the outer surface of the inner conductor **714**. A fluid **725** is circulated within one or both the first and second dielectric materials **716**, **718** via conduits **727** and **729** defined respectively therein. The relative temperature of the fluid **725** may be selectively controllable via circuitry controlled by the generator **300** to regulate thermal expansion of one or both the first and second dielectric materials **716**, **718** to position the inner conductor **714** relative to the outer conductor **712** to change the impedance of the inner conductor **714**. The fluid **725** may optionally or alternatively be disposed between the first and second dielectric materials **716**, **718** and be controlled in a similar manner.

While several embodiments of the disclosure have been shown in the drawings and/or discussed herein, it is not intended that the disclosure be limited thereto, as it is intended that the disclosure be as broad in scope as the art will allow and that the specification be read likewise. Therefore, the above description should not be construed as limiting, but merely as examples of particular embodiments. Those skilled in the art will envision other modifications within the scope and spirit of the claims appended hereto.

What is claimed is:

1. A coaxial cable, comprising:

an outer conductor and an inner conductor adapted to connect to an energy source; and

first and second dielectric materials disposed between the inner conductor and the outer conductor that position the inner conductor relative to the outer conductor in a first position, wherein the first dielectric material has a first coefficient of thermal expansion and the second dielectric material has a second coefficient of thermal expansion different from the first coefficient of thermal expansion.

2. The coaxial cable according to claim **1**, wherein the first and second dielectric materials are thermally expandable and contractible to position the inner conductor relative to the outer conductor from the first position to a second position different from the first position.

3. The coaxial cable according to claim **1**, wherein the first and second dielectric materials are at least one of thermally expandable and contractible to position the inner conductor relative to the outer conductor from the first position wherein the inner conductor is concentrically aligned with the outer conductor to a second position wherein the inner conductor is not concentrically aligned with the outer conductor.

4. The coaxial cable according to claim **1**, wherein the first dielectric material is selected from the group consisting of ABS Polymer Extruded, ABS Polymer Nylon Blend, PEKK Polyketone, PEEK Polyketone, Nylon PTFE Filled, Polycarbonate Extruded, LDPE (Polyethylene), Polyimide, PTFE Molded, Silica Aerogel and combinations thereof.

5. The coaxial cable according to claim **1**, wherein the second dielectric material is selected from the group consisting of ABS Polymer Extruded, ABS Polymer Nylon Blend, PEKK Polyketone, PEEK Polyketone, Nylon PTFE Filled, Polycarbonate Extruded, LDPE (Polyethylene), Polyimide, PTFE Molded, Silica Aerogel and combinations thereof.

6. The coaxial cable according to claim **1**, wherein the first and second dielectric materials define at least one space disposed therebetween.

7. The coaxial cable according to claim **1**, further comprising at least one of a shape memory alloy and a resistive heating element operatively associated with at least one of the first and second dielectric materials for regulating the thermal expansion of at least one of the first and second dielectric materials to position the inner conductor relative to the outer conductor.

8. The coaxial cable according to claim **1**, wherein a fluid is disposed between the first and second dielectric materials, the relative temperature of the fluid being selectively controllable to regulate thermal expansion of at least one of the first and second dielectric materials to position the inner conductor relative to the outer conductor.

9. The coaxial cable according to claim **1**, wherein at least one heating element is disposed within at a least one of the first and second dielectric materials, the relative temperature of the heating element being selectively controllable to regulate thermal expansion of at least one of the first and second dielectric materials to position the inner conductor relative to the outer conductor.

10. The coaxial cable according to claim **1**, wherein the first dielectric material holds the inner conductor and the second dielectric material mechanically supports the first material.

11. The coaxial cable according to claim **1**, wherein the energy source includes sensor circuitry that monitors at least one of the inner and outer conductors for determining the position of the inner conductor relative to the outer conductor.

12. The coaxial cable according to claim **11**, wherein the sensor circuitry is operably coupled to a means for regulating the thermal expansion of at least one of the first and second dielectric materials to position the inner conductor relative to the outer conductor to change the impedance of the inner conductor, the means for regulating including at least one of a shape memory alloy, a heat resistive element and a temperature controllable fluid.

13. A coaxial cable, comprising:

an outer conductor and an inner conductor adapted to connect to an energy source; and

at least one dielectric spacer disposed between the outer conductor and an inner conductor, the dielectric spacer including first and second dielectric materials disposed between the inner conductor and the outer conductor that position the inner conductor relative to the outer conductor in a first position, wherein the first dielectric material has a first coefficient of thermal expansion and the second dielectric material has a second coefficient of thermal expansion different from the first coefficient of thermal expansion.

14. The coaxial cable according to claim **13** further comprising a plurality of dielectric spacers spaced relative to one another along a length of the cable.

15. A coaxial cable, comprising:

an outer conductor and an inner conductor adapted to connect to an energy source;

at least one dielectric material disposed between the outer conductor and an inner conductor, wherein the dielectric material is thermally expandable to position the inner conductor relative to the outer conductor from a first position wherein the inner conductor is not concentrically aligned with the outer conductor to a second position wherein the inner conductor is more concentrically-aligned with the outer conductor; and

at least one heating element disposed within the dielectric material adapted to connect to an energy source for controlling the temperature thereof.

16. A coaxial cable according to claim **15** further comprising a plurality of heating elements disposed within the dielectric material, the temperature of each of the plurality of heating elements being selectively controllable to position the inner conductor relative to the outer conductor.

17. A coaxial cable according to claim **16** wherein the plurality of heating elements is disposed in a concentric array relative to the inner conductor.

18. A coaxial cable according to claim **15**, wherein the generator further comprises sensor circuitry which monitors the position of the inner conductor within the coaxial cable.

19. A method for controlling the impedance of a coaxial cable, the method comprising:

providing:

an outer conductor and an inner conductor;

first and second dielectric materials disposed between the inner conductor and the outer conductor, wherein the first dielectric material has a first coefficient of thermal expansion and the second dielectric material has a second coefficient of thermal expansion different from the first coefficient of thermal expansion;

energizing the cable;

determining an impedance of the inner conductor; and

causing at least one of the first and second dielectric materials to thermally expand or contract to move the inner conductor relative to the outer conductor to change the impedance of the coaxial cable.

20. A method according to claim **19** wherein the impedance of the coaxial cable is substantially matched to the impedance of at least one of a microwave generator and a microwave probe.

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